Unit 4

Syllabus

Digital Electronics: Number system & representation, Binary arithmetic, Introduction of Basic and Universal Gates, using Boolean algebra simplification of Boolean function. K Map Minimization upto 6 Variables.

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Number System

There are many different symbols are used in no.

(1) Binary → Base 2 (0, 1).
(2) Octal → Base 8 (0, 1, 2, 3, 4, 5, 6, 7)
(3) Decimal → Base 10 (0, 1, 2, 3, 4, 5, 6, 7, 8, 9)
(4) Hexadecimal → Base 16 (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F)

Conversion

→ Any no to decimal number system

Ex $[101.010]_2$ to decimal

1×2^2, 0×2^1, 1×2^0, 0×2^{-1}, 1×2^{-2}, 0×2^{-3}

$4+0+1+0+2^{-2}+0$

$5+\frac{1}{4} = (5.25)_{10}$

Q $[4021.2]_5$

4×5^3, 0×5^2, 2×5^1, 1×5^0, 2×5^{-1}

$= 500+10+1+0.4$

$= [511.4]_{10}$

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Unit I

Number System

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4. Hexadecimal → Base 16 (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F)

Conversion

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Ex: $[101.010]_2$ to decimal

1×2^2, 0×2^1, 1×2^0, 0×2^{-1}, 1×2^{-2}, 0×2^{-3}

$4+0+1+0+2^{-2}+0$

$5+\frac{1}{4} = (5.25)_{10}$

Q. $[4021.2]_5$

4×5^3, 0×5^2, 2×5^1, 1×5^0, 2×5^{-1}

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① $[13]_{10}$ to biamny

2	13	1
2	6	0
2	3	1
	1	

$[1101]_2$

② [13.31]

2	13	1
2	6	0
2	3	1
	1	

$0.31 \times 2 = 0.62$ — 0

$0.62 \times 2 = 1.24$ — 1

$0.24 \times 2 = 0.48$ — 0

So $[13.31]_{10} \rightarrow [1101.010]_2$

③ $[546.976]_{10} \rightarrow [\ ]_8$

8	546	2
8	68	4
8	8	0
	1	

$0.976 \times 8 = 7.808$ — 7

$0.808 \times 8 = 6.464$ — 6

So

$[1042.76]_8$

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Q $[336.234]_{10} \rightarrow [\quad]_{16}$

16	336	
16	21	0
	1	5

$0.234 \times 16 = 3.744 \quad 3$

$0.744 \times 16 = 11.904 \quad 11$

$0.904 \times 16 = 14.469 \quad 14$

$= (150.3BE)_{16}$

→ Any base to any base

$[Num]_{10} \longrightarrow [decimal]_{10} \longrightarrow [Num]_{r}$

Q $[111011] \rightarrow [\quad]_8$

$2^5 + 2^4 + 2^3 + 2 + 1 = [59]_{10}$

8	59	
	7	3

$[73]_8$

Q $[323]_4 \rightarrow [\quad]_{16}$

$3 \times 4^2 + 2 \times 4 + 3$

$[59]_{10}$

16	59	
	3	11

$\Rightarrow [3B]_{16}$

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① Write Decimal no 0 to 15 in Binary

0	0 0 0 0
1	0 0 0 1
2	0 0 1 0
3	0 0 1 1
4	0 1 0 0
5	0 1 0 1
6	0 1 1 0
7	0 1 1 1
8	1 0 0 0
9	1 0 0 1
10	1 0 1 0
11	1 0 1 1
12	1 1 0 0
13	1 1 0 1
14	1 1 1 0
15	1 1 1 1

Binary Arthematic

→ **Addition:**

$$\begin{array}{r} \overset{1}{2}\,3 \\ 3\,9 \\ \hline 6\,2 \end{array}_{10}$$

Sum − Base
12 − 10 = 2

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Q

```
   1
   1 1 0 1
 + 0 1 0 1
 ---------
 1 0 0 1 0 (2)
```

2 - 2 = 0

Q

```
   1   1   1
   1   0   1   0
   0   1   0   1
   1   1   1   1
   -------------
 1 1   1   1   0 (2)
```

(1 1 ↓ Binary of 3)

2 - 2 = 0
3 - 2 = 1

Q

```
   1 1 1 2 1 1 1
   0 1 1 0 1 0 1 0
   0 0 0 0 1 0 0 0
   1 0 0 0 0 0 0 1
   1 1 1 1 1 1 1 1
   ---------------
 1 1 1 1 1 0 0 1 0 (2)
```

Note: If no of 1's in a column even then Sum = 0
If no of 1's in a column odd then Sum = 1
each pair gives carry to the next line

→ Subtraction :-

```
   6   10+2
   7   2
 - 1   5
 ---------
   5   7 (10)
```


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(Q)

$$\begin{array}{r} 1\,0\,1\,0 \\ -\;0\,1\,1\,1 \\ \hline 0\,0\,1\,1 \end{array}_2$$

Complements

Complement simplify substraction because it perform subtraction with the help of addition.

Complements are 2 types

1. r's complement
2. (r-1)'s complement

→ r's complement :-

If $[N]_r$ then r's complement is

$$= \begin{cases} r^n - N & \text{if } N \neq 0 \\ 0 & \text{if } N = 0 \end{cases}$$

where n is the number of digits in integer part

(Q) $[10110]_2$ 2's complement is :-

$2^5 - 10110$

$32 - 10110$

$100000 - 10110$

2's complement = 1010

2	32 — 0
2	16 — 0
2	8 — 0
2	4 — 0
2	2 — 0
	1

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→ (r-1)'s Complement

$$(r-1)'s \text{ complement} = \begin{cases} r^n - r^{-m} - N & N \neq 0 \\ 0 & N = 0 \end{cases}$$

where m is the number of digits in fractional part
n " " " integer.

Q [101100]$_2$ 1's complement

$2^6 - 1 - 101100$
$63 - 101100 = 111111 - 101100$
[010011]

Subtraction using 2's Complement

Q [110010]$_2$ − [10000]$_2$

Step 1 :- M = 110010
N = 10000
Balance : N = 010000

Step 2 :- Take 2's complement of N
N' = 110000

Step 3 :- M + N'
110010 + 110000
(1) 100010
discard ⇒ 100010 Ans

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Q [10000]$_2$ − [110010]$_2$

M = 010000

N = 110010

N′ = 001110

M + N′

010000 + 001110

011110

Carry not generate So number is −ve

Now taking 2's complement of result

= − 100010 Ans

Q 1010 − 0111

= 0011

Q 111111 − 101100

= 10011

Q 101100 − 111111

= − 10011

Subtraction using 1's complement

Q [110010]$_2$ − [10000]$_2$

M = 110010

N = 010000

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Take 1's complement of N.

N' = 101111

M+N' = 110010 + 101111

= (1)100001

+ 1

100010 Ans

(i) [10000]$_2$ - [110010]

M = 010000

N = 110010

N' = 001101

M+N' = 010000 + 001101

= 011101

Carry not Generate so take 1's complement of res

= -100010 Ans

and number is -ve

(i) 101100 - 111111

(i) 1111 - 1010

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Boolean Algebra

Binary variable can be represented by X, Y, A, B ... etc.
All binary variable can have 2 values i.e. 0 and 1

Rules for minimize Boolean functions:

(1) $A + 0 = A$
(2) $A + 1 = 1$
(3) $A + A = A$
(4) $A + \bar{A} = 1$
(5) $A \cdot (B + C) = AB + AC$
(6) $A + AB = A$
(7) $A + \bar{A}B = A + B$
(8) $AB + A\bar{B} = A$
(9) $AB + \bar{A}C = (A + C)(B + \bar{A})$
(10) $AB + \bar{A}C + BC = AB + \bar{A}C$
(11) $A \cdot 1 = A$
(12) $A \cdot 0 = 0$
(13) $A \cdot A = A$
(14) $A \cdot \bar{A} = 0$
(15) $A + BC = (A + B)(A + C)$
(16) $A(A + B) = A$
(17) $A(\bar{A} + B) = AB$
(18) $(A + B)(A + \bar{B}) = A$
(19) $(A + B)(\bar{A} + C) = AC + \bar{A}B$
(20) $(A + B)(\bar{A} + C)(B + C)$
$= (A + B)(\bar{A} + C)$

Q minimize :- $(A + B + C)(A + B + \bar{C})(A + \bar{B} + C)$

$(AA + AB + A\bar{C} + BA + BB + B\bar{C} + AC + CB + C\bar{C})(A + \bar{B} + C)$

$(A + AB + A\bar{C} + B\bar{C} + AC + CB)(A + \bar{B} + C)$

$(A + B + A)(A + \bar{B} + C)$

$(A + B)(A + \bar{B} + C)$

$A + A\bar{B} + AC + AB + BC$

$A + A + BC$

$(A + BC)$ Ans

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① Minimize: $AB\bar{C}\bar{D} + AB\bar{C}D + A\bar{B}\bar{C}D + ABCD + ABCD + ABC\bar{D} + A\bar{B}C\bar{D}$

$AB\bar{C}\bar{D} + A\bar{C}D + ABC + A\bar{B}C$

$AB\bar{C}\bar{D} + A\bar{C}D + AC$

$A\bar{C}(B\bar{D} + D) + AC$

$A\bar{C}(B + D) + AC$

$A\bar{C}B + A\bar{C}D + AC$

$A(\bar{C}B + C) + A\bar{C}D$

$A(B + C) + A\bar{C}D$

$AB + AC + A\bar{C}D$

$AB + A(C + \bar{C}D)$

$AB + A(C + D)$

$AB + AC + AD$ Ans.

② Minimize :- $\bar{P}(P + QR) + (PQ + \bar{Q}R)$

$\bar{P}QR + PQ + \bar{Q}R$

$R(\bar{P}Q + \bar{Q}) + PQ$

$R(\bar{P} + Q) + PQ$

$R\bar{P} + RQ + PQ$ Ans

③ Minimize :- $\bar{A}(\bar{m} + \bar{A})(m + \bar{m}A)$

$\bar{A}\bar{m}(m + A)$ $(\bar{A}\bar{m} + \bar{A})(m + A)$

$\bar{A}\bar{m}m + \bar{A}\bar{A}m$

$\bar{A}(\bar{A}m + \bar{A}m)$

$\bar{A}\bar{m}m + \bar{A}\bar{m}A + \bar{A}m + \bar{A}A$

$= \bar{A}m$

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Q Minimize: $F\bar{T} + \bar{F} + \bar{T}\cdot\bar{F}$

$\bar{T} + \bar{F}$ Ans

Q Simplify: $AV(A+\bar{V}) + A(V+\bar{V})$

$AV + A$

A Ans

Q $F = (J + K\bar{L})(J\bar{K} + L)$

$J\bar{K} + JL$

$J(\bar{K} + L)$ Ans

De-Morgan Law

$\overline{ABCD\ldots} \Rightarrow \bar{A} + \bar{B} + \bar{C} + \bar{D} + \ldots$

$\overline{A+B+C+D\ldots} \Rightarrow \bar{A}\,\bar{B}\,\bar{C}\,\bar{D}\ldots$

Q Reduce: $\overline{F = (x\bar{y}) + (\bar{x}y)}$

$= (\overline{x\bar{y}})(\overline{\bar{x}y})$

$= (\bar{x}+y)(x+\bar{y})$ Ans

Q $y = \overline{(a+\bar{b}+c+\bar{a}) + (b+\bar{c})}$

$= (\overline{a+\bar{b}+c+\bar{a}})(\overline{b+\bar{c}})$

$= (\bar{a}b\bar{c}d)(\bar{b}c)$

$= \bar{a}b\bar{b}\bar{c}cd = 0$

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Conical / standard form

Sum of product (SOP)

Ex $xy + \bar{y}z + zx$

→ Under SOP each product term is called minterms

→ Each minterm are not contain all variable than it is called standard form

→ If each minterm contain all variable than it is called conical form

→ Convert std to conical

$xy + yz + zx$

$xy(z+\bar{z}) + yz(x+\bar{x}) + zx(y+\bar{y})$

$xyz + xy\bar{z} + xyz + \bar{x}yz + xyz + x\bar{y}z$

$xyz + xy\bar{z} + \bar{x}yz + x\bar{y}z$

111 110 011 101

$\sum_{m}(3, 5, 6, 7)$

Product of Sum (POS)

$(\bar{x}+y)(x+\bar{y})(\bar{z}+x)$

→ under POS each sum term is called maxterm

→ Each maxterm are not contain all variable than it is called Standard form

If each maxterm contain all variable than it is called Conical form

$(\bar{x}+y)(x+\bar{y})(\bar{z}+x)$

$(\bar{x}+y+z\bar{z})(x+\bar{y}+z\bar{z})$

$(\bar{z}+x+y\bar{y})$

$(\bar{x}+y+z)(\bar{x}+y+\bar{z})(x+\bar{y}+z)$

$(x+\bar{y}+\bar{z})(x+y+z)(x+\bar{y}+\bar{z})$

⇒ $(\bar{x}+y+z)(\bar{x}+y+\bar{z})(x+\bar{y}+z)$

100 101 010

$(x+\bar{y}+\bar{z})(x+y+z)$

011 000

$\prod_{m}(0, 2, 3, 4, 5)$

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Q) Convert SOP to POS

$F = A + \bar{B} C$

Sol

$= A(B+\bar{B})(C+\bar{C}) + (A+\bar{A})\bar{B}C$

$= (AB + A\bar{B})(C+\bar{C}) + A\bar{B}C + \bar{A}\bar{B}C$

$= ABC + AB\bar{C} + A\bar{B}C + A\bar{B}\bar{C} + A\bar{B}C + \bar{A}\bar{B}C$

$= ABC + AB\bar{C} + A\bar{B}\bar{C} + \bar{A}\bar{B}C + A\bar{B}C$

111 110 100 001 101

$\sum_m (1, 4, 5, 6, 7)$

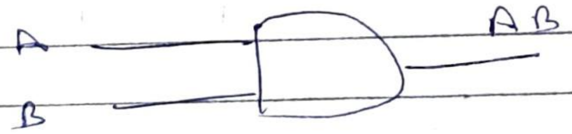
$\prod_m (0, 2, 3)$

$(A+B+C)(A+\bar{B}+C)(A+\bar{B}+\bar{C})$

Logic Gates

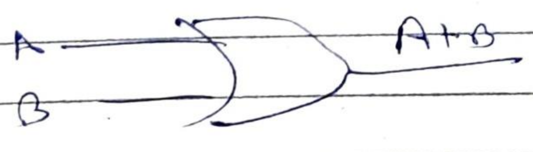
Basic Gates :-

① AND Gate



A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

② OR Gate



A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

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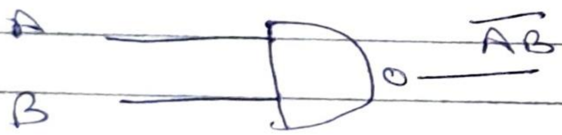
③ **Not Gate :-**

A	Y
0	1
1	0

Universal Gates

① **NAND Gate :-**



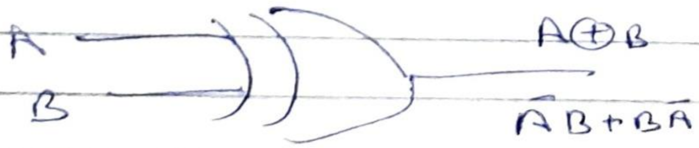
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

② **NOR Gate :-**

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

Special purpose Gate :-

① **Ex OR**



A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

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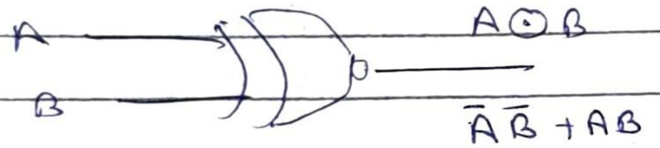
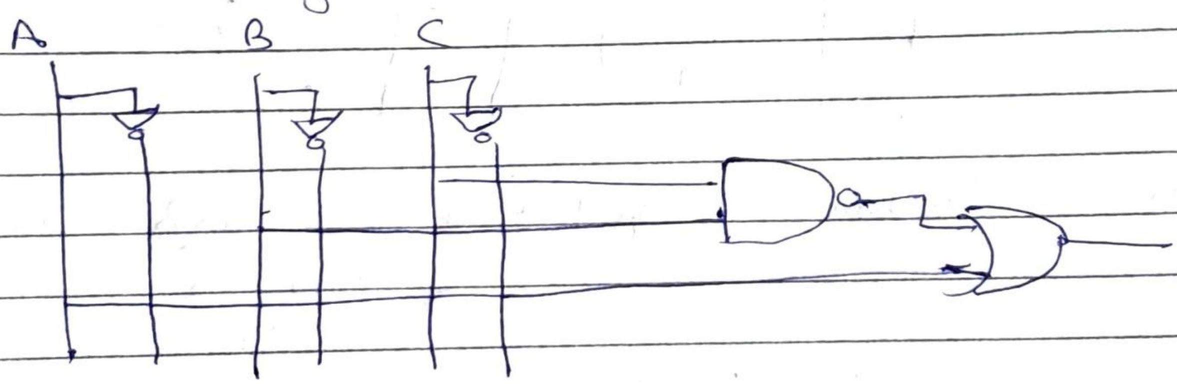
(2) Ex NOR

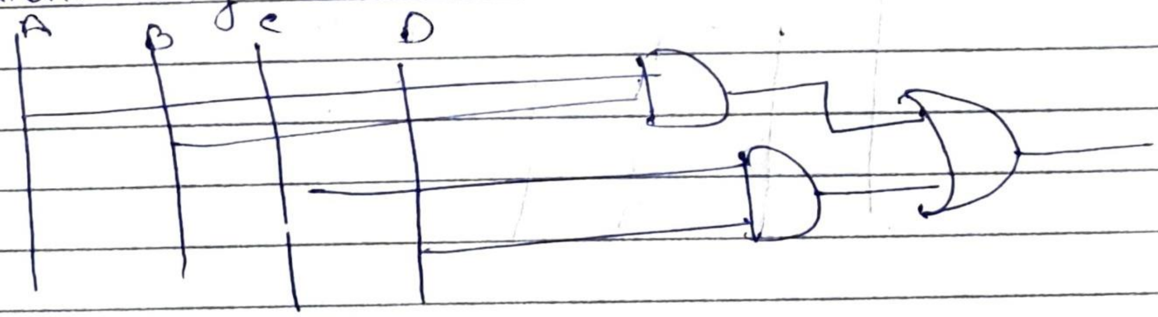


A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

(d) Implement using Basic Gate $A + \bar{B}C$



(c) Implement using Basic Gate : $AB + CD$



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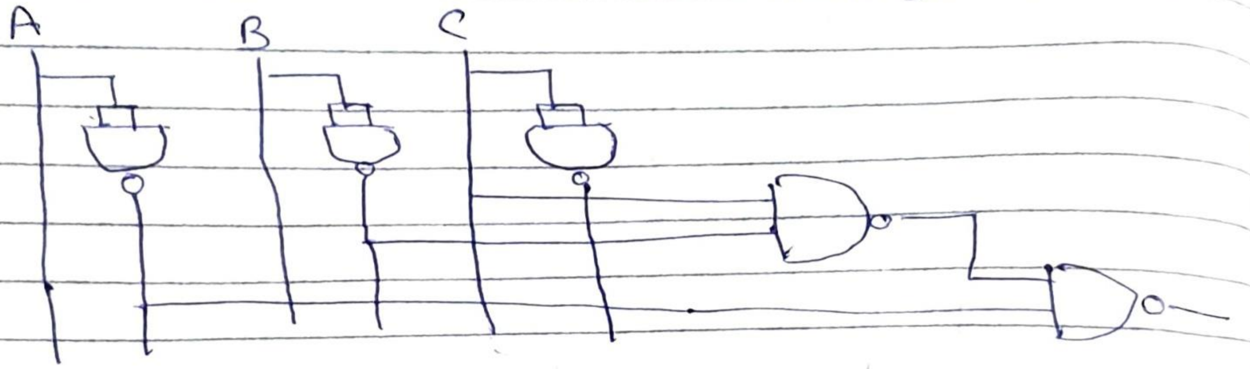
① Implement using NAND Gate :- $A + \bar{B}C$

$$\overline{\overline{A + \bar{B}C}}$$

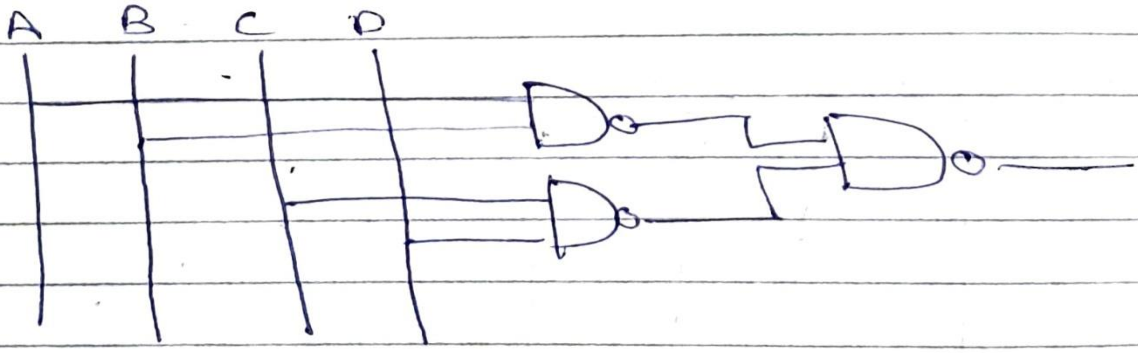
$$\overline{\bar{A}\,(\overline{\bar{B}C})}$$



② Implement using NAND Gate :- $AB + CD$

$$\overline{\overline{AB + CD}}$$

$$\overline{\overline{AB}\;\overline{CD}}$$



③ Implement using NOR Gate $A + \bar{B}C$

$$\overline{\overline{A + \bar{B}C}}$$

$$\overline{\bar{A}\,(\overline{\bar{B}C})}$$

$$\overline{\bar{A}\,(B + \bar{C})}$$

$$A + \overline{B + \bar{C}}$$

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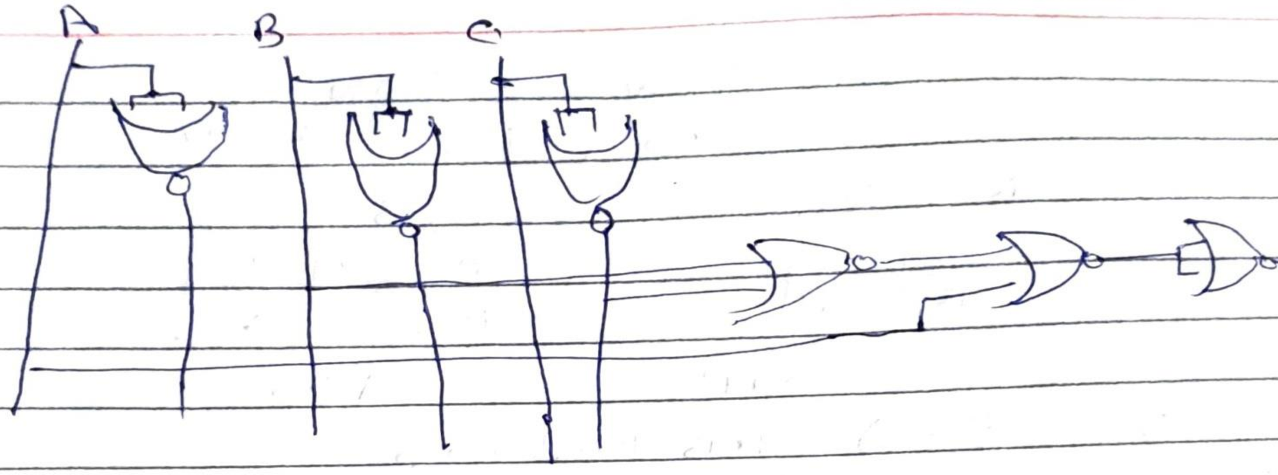
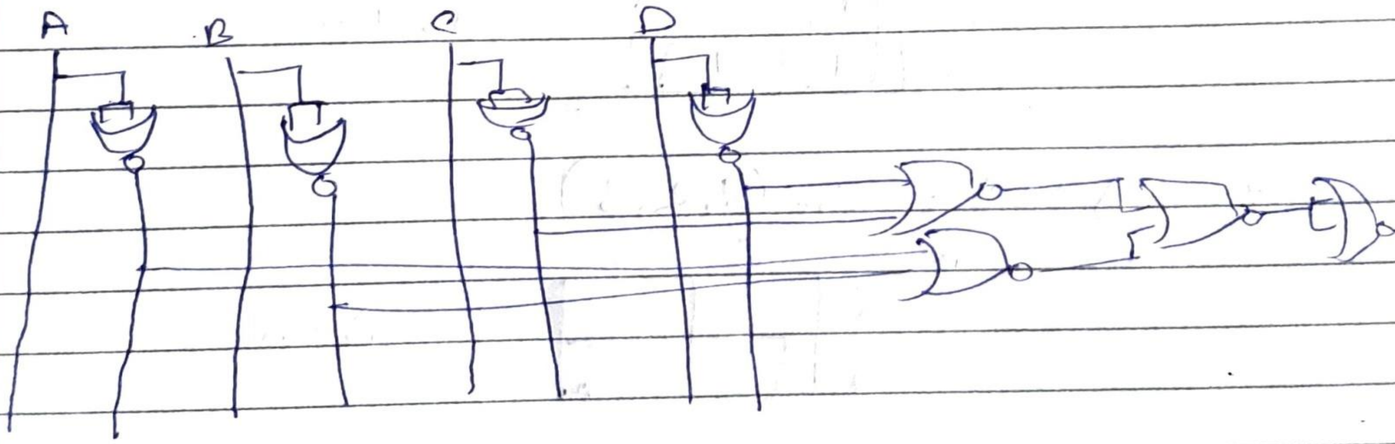


Q Implement using NOR Gate AB + CD

$\overline{\overline{A}+\overline{B}} + \overline{\overline{C}+\overline{D}}$



K map

Boolean algebra deals with 0 and 1 but not X (don't care) condition. K-map deals with don't care 0 and 1

K map gives minimized solution

K-map does not gives unique solution

No of cells in any K map = 2^n (n = no of variable)

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2 variable Kmap

no of cells = $2^2 = 4$

A \ B	$\bar{B}$	B
$\bar{A}$	0	1
A	2	3

SOP

A \ B	B	$\bar{B}$
A	0	1
$\bar{A}$	2	3

POS

(1) $f(AB) = \bar{A}\bar{B} + AB + A\bar{B}$

$\sum m(0, 2, 3)$

A \ B	$\bar{B}$	B
$\bar{A}$	1	
A	1	1

$\bar{B} + A$

(2) $f(AB) = \sum m(1, 2, 3)$

A \ B	$\bar{B}$	B
$\bar{A}$		1
A	1	1

$B + A$

(3) $f(AB) = (\bar{A} + \bar{B})(A + B)(A + \bar{B}) \Rightarrow \prod m(0, 1, 3)$

A \ B	B	$\bar{B}$
A	0	0
$\bar{A}$		0

$A\bar{B}$

(4) $\prod m(1, 2, 3)$

A \ B	B	$\bar{B}$
A		0
$\bar{A}$	0	0

$\bar{A}\bar{B}$

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3 variable kmap

No of cell $= 2^3 = 8$

A \ BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	0	1	3	2
A	4	5	7	6

SOP

A \ BC	$B+C$	$B+\bar{C}$	$\bar{B}+\bar{C}$	$\bar{B}+C$
A	0	1	3	2
$\bar{A}$	4	5	7	6

POS

Q Minimize $ab + \bar{b}c + bc$

$ab(c+\bar{c}) + (a+\bar{a})\bar{b}c + (a+\bar{a})bc$

$abc + ab\bar{c} + a\bar{b}c + \bar{a}\bar{b}c + abc + \bar{a}bc$

$abc + ab\bar{c} + a\bar{b}c + \bar{a}\bar{b}c + \bar{a}bc$

$\sum_m (1, 3, 5, 6, 7)$

a \ bc	$\bar{b}\bar{c}$	$\bar{b}c$	bc	$b\bar{c}$
$\bar{a}$		1	1	
a		1	1	1

$c + ab$

Q $\sum m(0, 1, 4, 5, 6)$

A \ BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1	1		
A	1	1		1

$\bar{b} + a\bar{c}$

Q Draw kmap of $A \odot B \odot C$ or $A \oplus B \oplus C$

A \ BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$		1		1
A	1		1	

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4 variable K map

No of cells = $2^4 = 16$

AB \ CD	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	0	1	3	2
$\bar{A}B$	4	5	7	6
AB	12	13	15	14
$A\bar{B}$	8	9	11	10

SOP

AB \ CD	$C+D$	$C+\bar{D}$	$\bar{C}+\bar{D}$	$\bar{C}+D$
$A+B$	0	1	3	2
$A+\bar{B}$	4	5	7	6
$\bar{A}+\bar{B}$	12	13	15	14
$\bar{A}+B$	8	9	11	10

Q) $\Sigma m(1,2,4,5,6,7,8,9,10,11)$

AB \ CD	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$		1		1
$\bar{A}B$	1	1	1	1
AB				
$A\bar{B}$	1	1	1	1

$\bar{A}B + A\bar{B} + \bar{A}\bar{C}D + \bar{A}C\bar{D}$

Q) $\Sigma m(0,1,2,3,8,9,10,11)$

AB \ CD	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	1	1	1	1
$\bar{A}B$				
AB				
$A\bar{B}$	1	1	1	1

$\bar{B}$

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Q $\Sigma m(0,1,5,7,8,10,14,15)$

AB \ CD	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	1	1		
$\bar{A}B$		1	1	
AB			1	1
$A\bar{B}$	1			1

Ans $\bar{B}\bar{C}D + \bar{A}\bar{C}D + BCD + AC\bar{D}$

Ans $\bar{A}\bar{B}\bar{C} + \bar{A}BD + ABC + A\bar{B}\bar{D}$

5 variable Kmap

No of cells $= 2^5 = 32$ → 16, 16

$\bar{A}$

BC \ DE	$\bar{D}\bar{E}$	$\bar{D}E$	DE	$D\bar{E}$
$\bar{B}\bar{C}$	0	1	3	2
$\bar{B}C$	4	5	7	6
BC	12	13	15	14
$B\bar{C}$	8	9	11	10

A

BC \ DE	$\bar{D}\bar{E}$	$\bar{D}E$	DE	$D\bar{E}$
$\bar{B}\bar{C}$	16	17	19	18
$\bar{B}C$	20	21	23	22
BC	28	29	31	30
$B\bar{C}$	24	25	27	26

Q $\Sigma(0,1,6,13,14,15,16,17,22,25,27,30)$

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Date:
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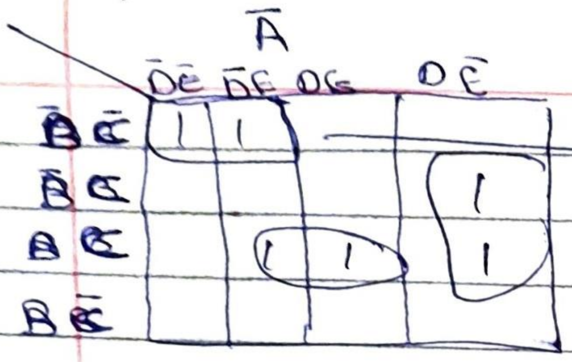
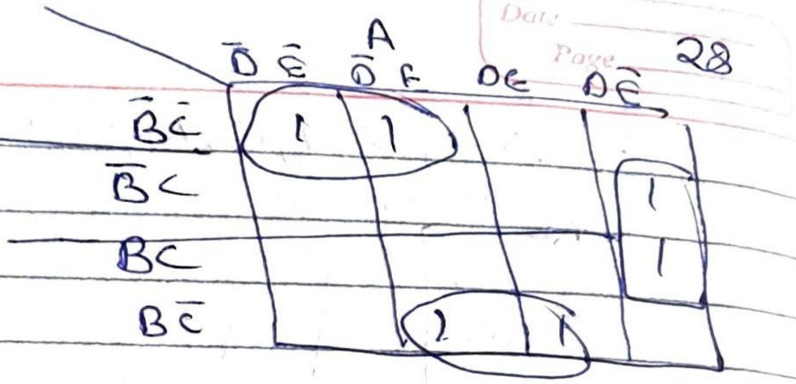


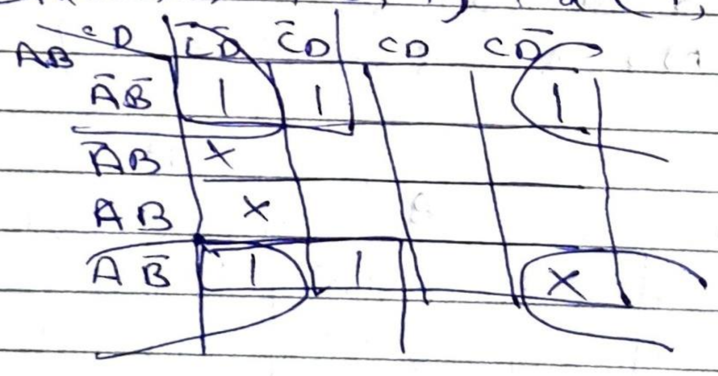


$\bar{D}\bar{B}\bar{C} + D\bar{E}C + BCE\bar{A} + B\bar{C}EA$

Don't care condition

Don't care means uncertain value it may be 0 and 1

Q. $\sum m(0,1,2,8,9) + d(4,10,12)$



$\bar{B}\bar{C} + \bar{B}\bar{D}$

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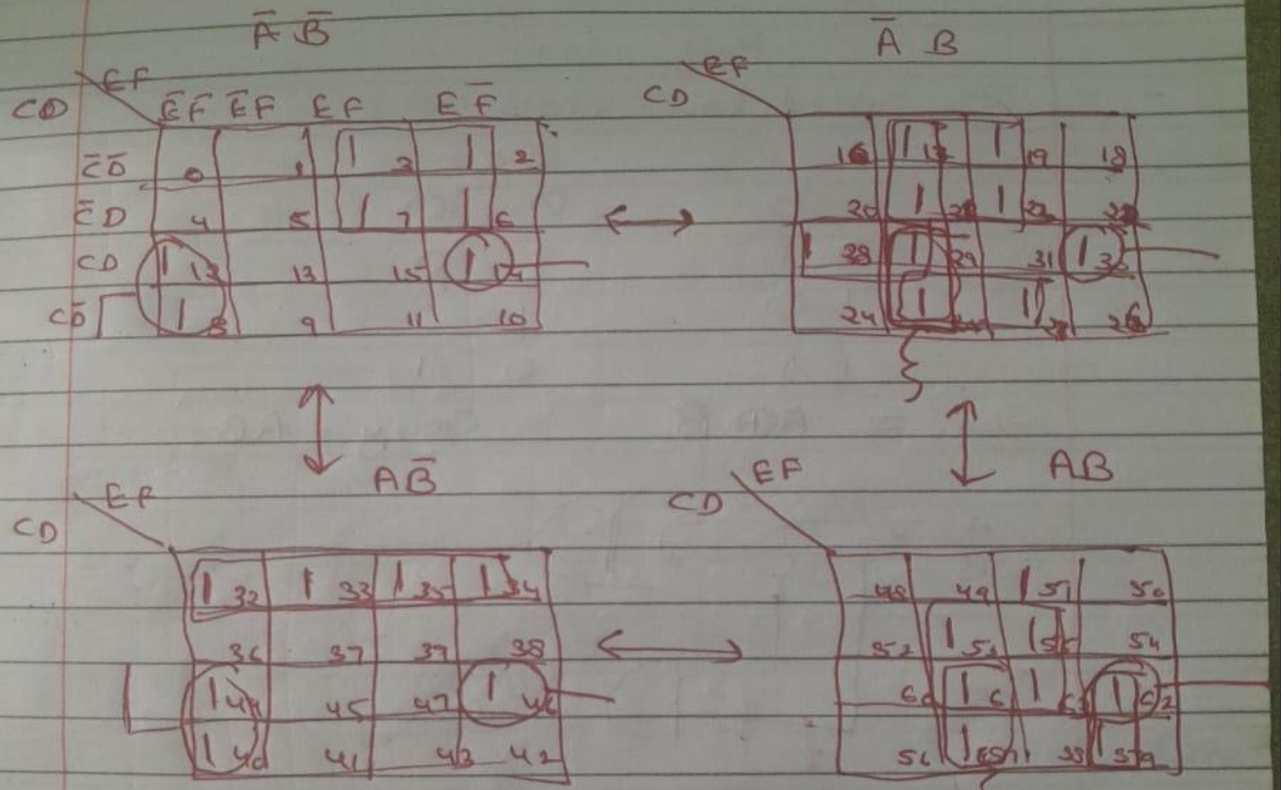
0 - 63

$2^6 = 64$

6 variable Kmap

① $\Sigma m(2,3,6,7,8,12,14,17,19,21,23,25,27,28,29,30,32,33,34,35,40,44,46,49,51,53,55,57,59,61,62,63)$



$\bar{A}\bar{B}\bar{C}E + \bar{A}B\bar{C}F + \bar{A}B\bar{E}F + \bar{A}BCD\bar{E} + \bar{A}BC\bar{D}F$
$+ A\bar{B}\bar{C}\bar{D} + ABDE + ABCE\bar{F} + \bar{B}C\bar{E}\bar{F}$
$+ BC\bar{E}F + CDE\bar{F}$

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